Novel Corrosion Protection Methods for Aluminum and Magnesium Alloys

Army Corrosion Summit
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Outline

- Process for increasing the corrosion resistance of Al alloys
  - Novelis Fusion™ Process
- Stannate chemical conversion coatings on Mg alloys
  - Advantages and problems with Mg alloys
  - AZ91D and EV31A-T6 alloys
  - Surface pretreatment and stannate concentrations
  - EIS and linear polarization results
  - Microstructures
- Sacrificial anode design

Mg Alloys

Advantages of Mg alloys

- Specific modulus (E/ρ) similar to Fe, Al, and Ti alloys
- Mg alloys are often superior to plastics for stiffness critical applications

Design for Corrosion Resistance!

•Alloy Selection

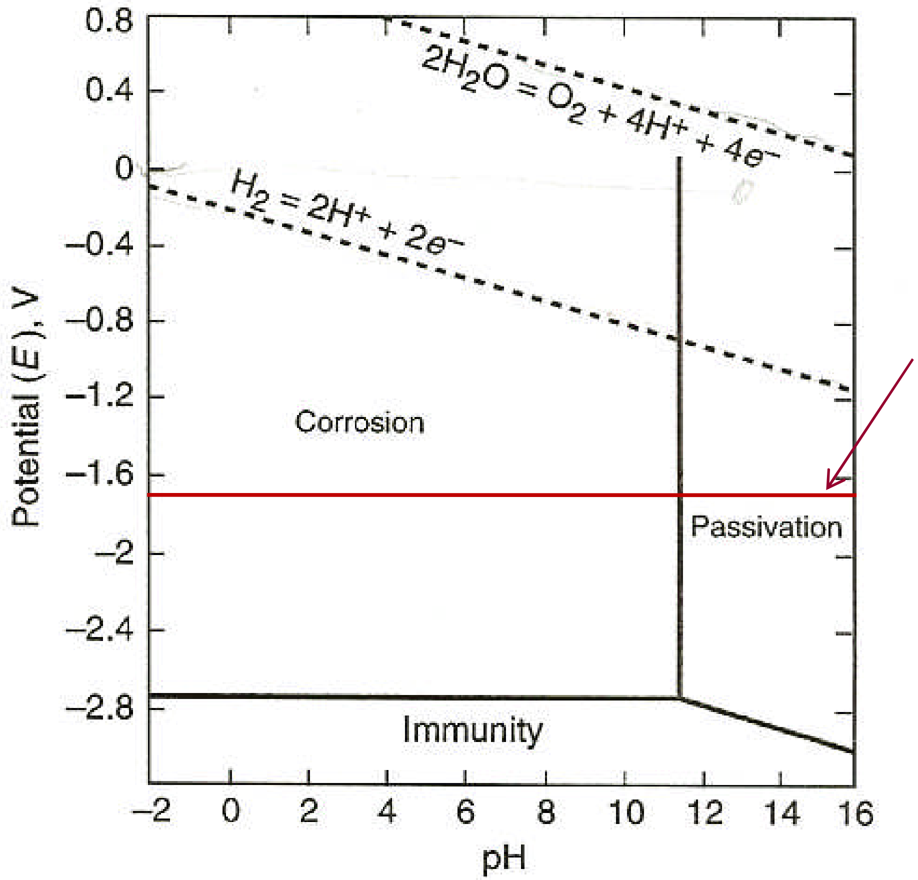
•Service Environment

- •Bare vs. Coatings
- •Coatings vs. Cost Trade Studies
- •Purity Level vs. Corrosion Resistance vs. Cost

Problems with Mg Alloys

- Chemical Reactivity
  - Corrosion susceptibility of wrought products and castings
  - Complicates liquid metal processing
- HCP crystal structure so fewer slip systems than mild steels (BCC) and Al alloys (FCC)

Open Circuit Potential of Mg



Potential vs. pH diagram for Mg

Typical Open Circuit Potential value of Mg alloys in aqueous solutions.

Corrosion Mitigation via Conversion Coatings

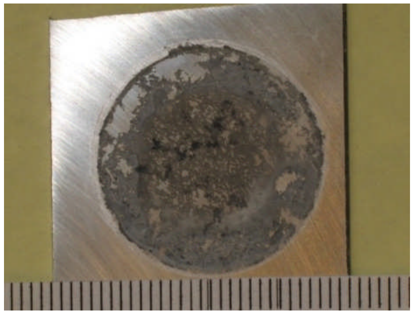
Stannate-based conversion coatings for AZ91D and EV31A-T6 alloys

- **Effect of surface modification prior to stannate coatings**
- **Effect of stannate concentration**

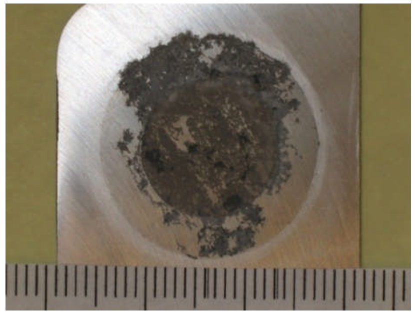
	AZ91D	EV31A-T6
Alloy Type	High Pressure Die Cast	Sand Cast
Density	1.81 g/cm^3	1.82 g/cm^3
Typical Yield Strength	115 MPa	154 MPa

Stannate coated AZ91D (One week in 3.5% NaCl)

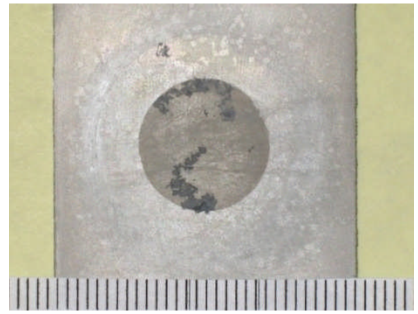
Blank



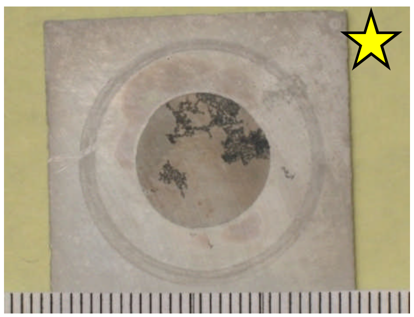
Alkaline



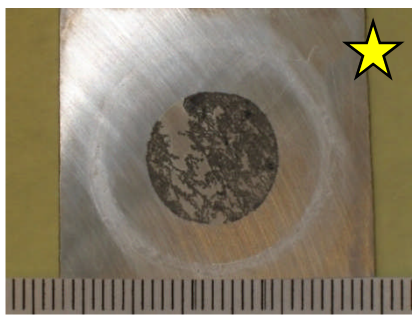
Acidic

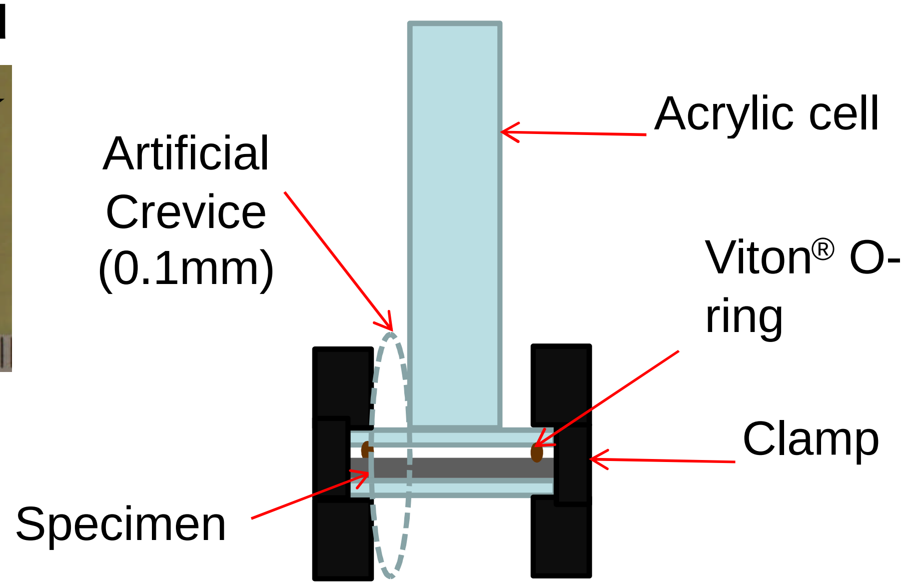


Alkaline/Acidic

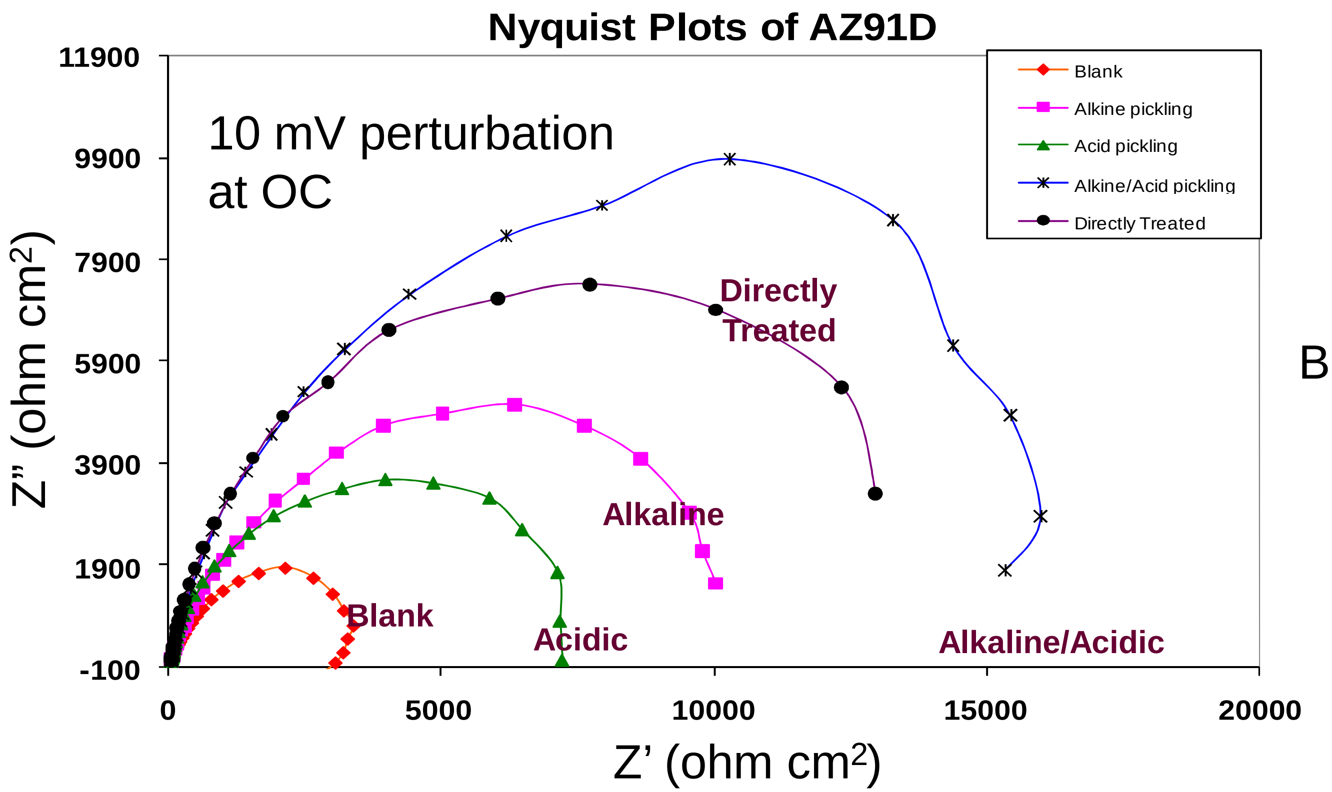


Directly Treated





EIS Analysis of Passive Film

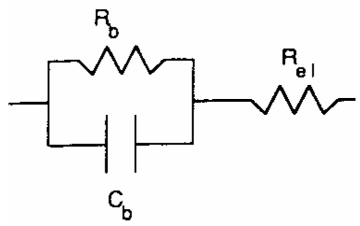


EIS after one week of immersion in NaCl solution

$$Z = Z' - jZ''$$

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{i\omega C}$$

Basic Equivalent Circuit



Effects of Stannate Coating on AZ91D Corrosion Rates

Sample	Blank	Stannate Coated			
Surface Modification	None	Alkaline	Acidic	Alkaline/ Acidic	Directly treated
Ecorr (VSCE)	-1.57	-1.56	-1.54	-1.54	-1.59
Icorr (µA/cm2)	61.3	30.0	1.9	2.3	**1.4**
Rp (KΩ cm2)	0.83	0.86	14.00	11.11	**18.1**
Corrosion rate (µm/yr)	350	170	110	130	**80.0**

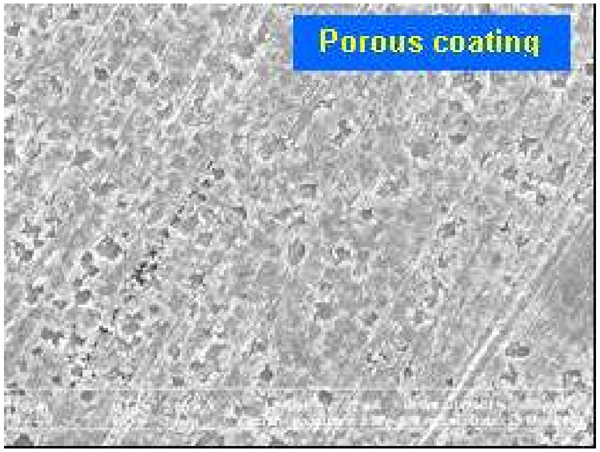
Linear polarization measurements after 30 minutes of immersion in 3.5% NaCl solution

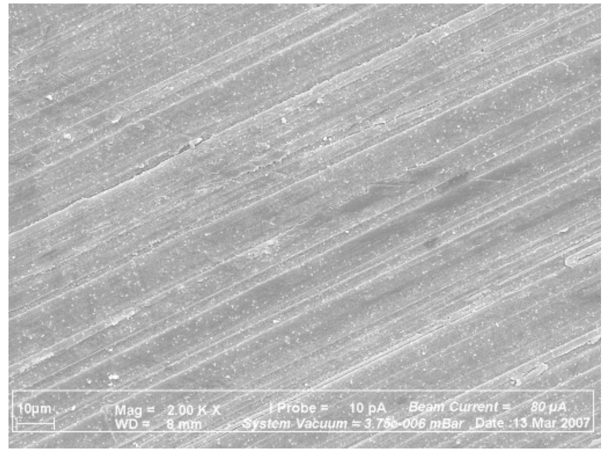
Alloy	Corrosion Rate (µm/yr)
AZ91D	254
EV31A-T6	432

ASTM B117 Salt Spray

SEM Images of Passive Film

Before Corrosion

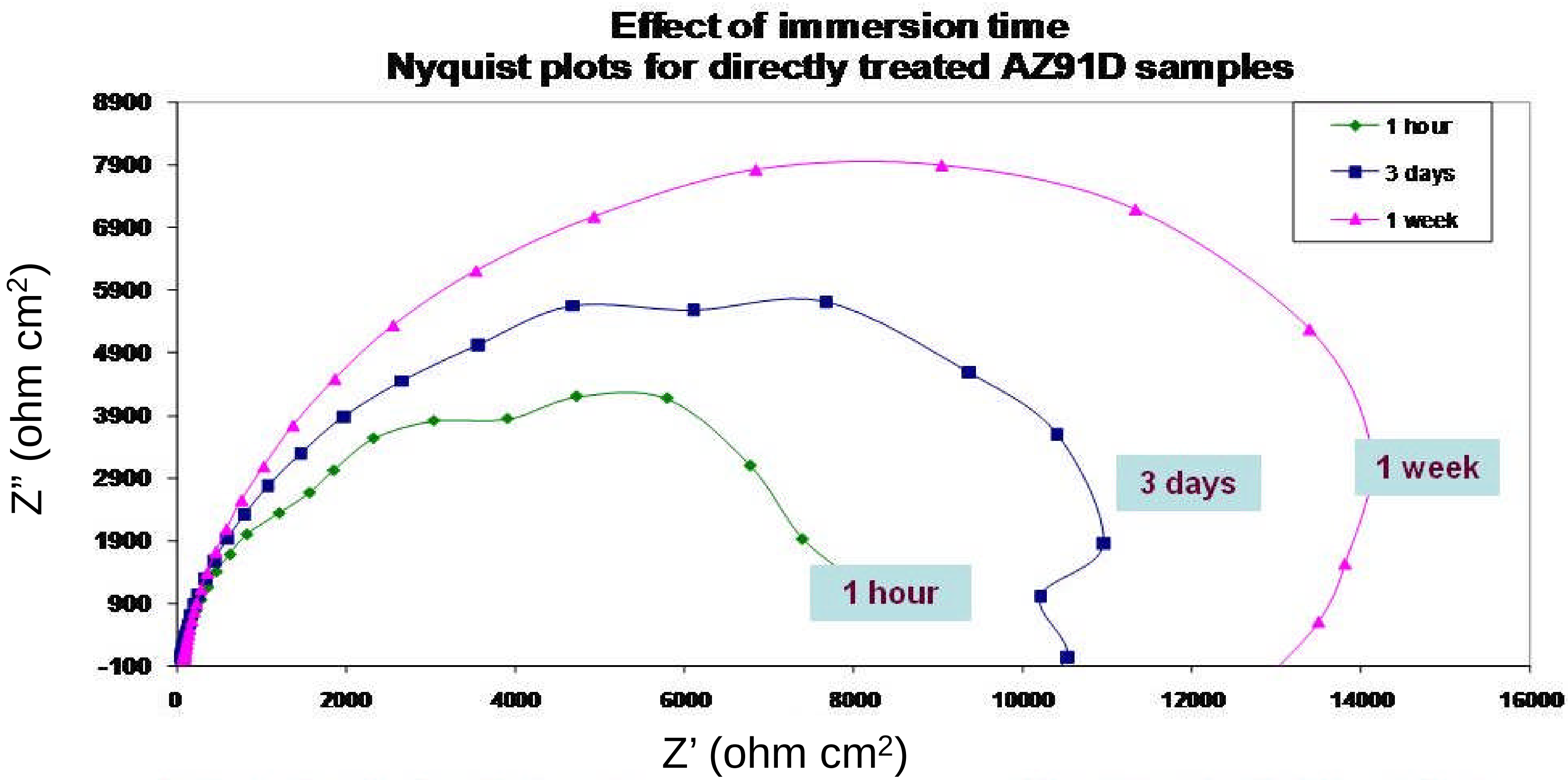




Alkaline/Acidic | **Directly treated**

After Corrosion

Effect of Immersion Time

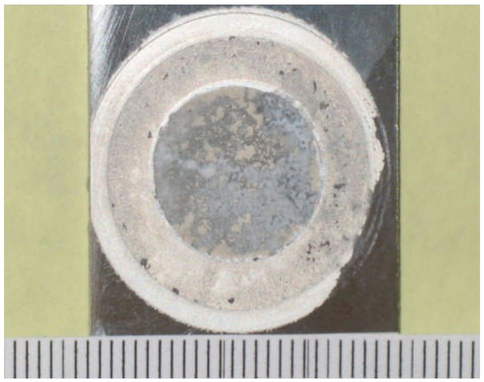


EIS of directly treated samples for longer immersion times in NaCl solution

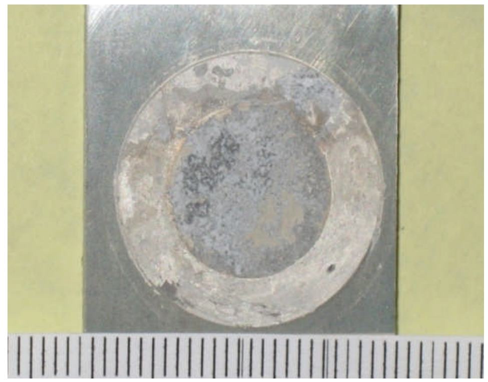
Corrosion protection of EV31A-T6

Stannate coated EV31A-T6 after seven days in NaCl

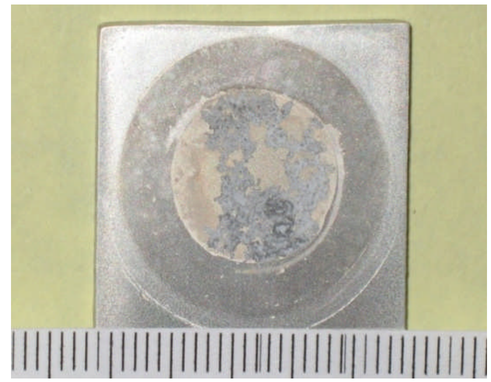
Blank



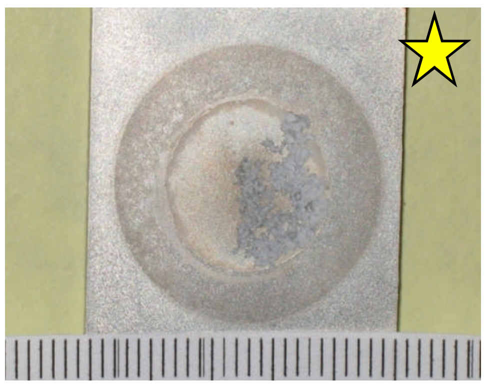
Alkaline



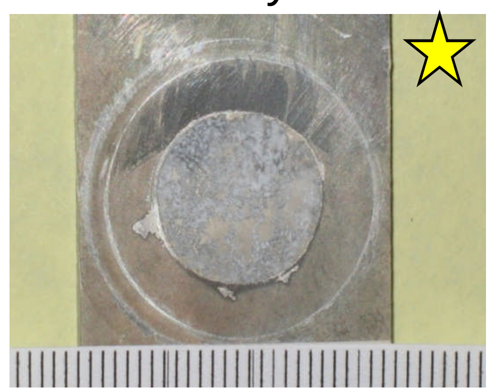
Acidic



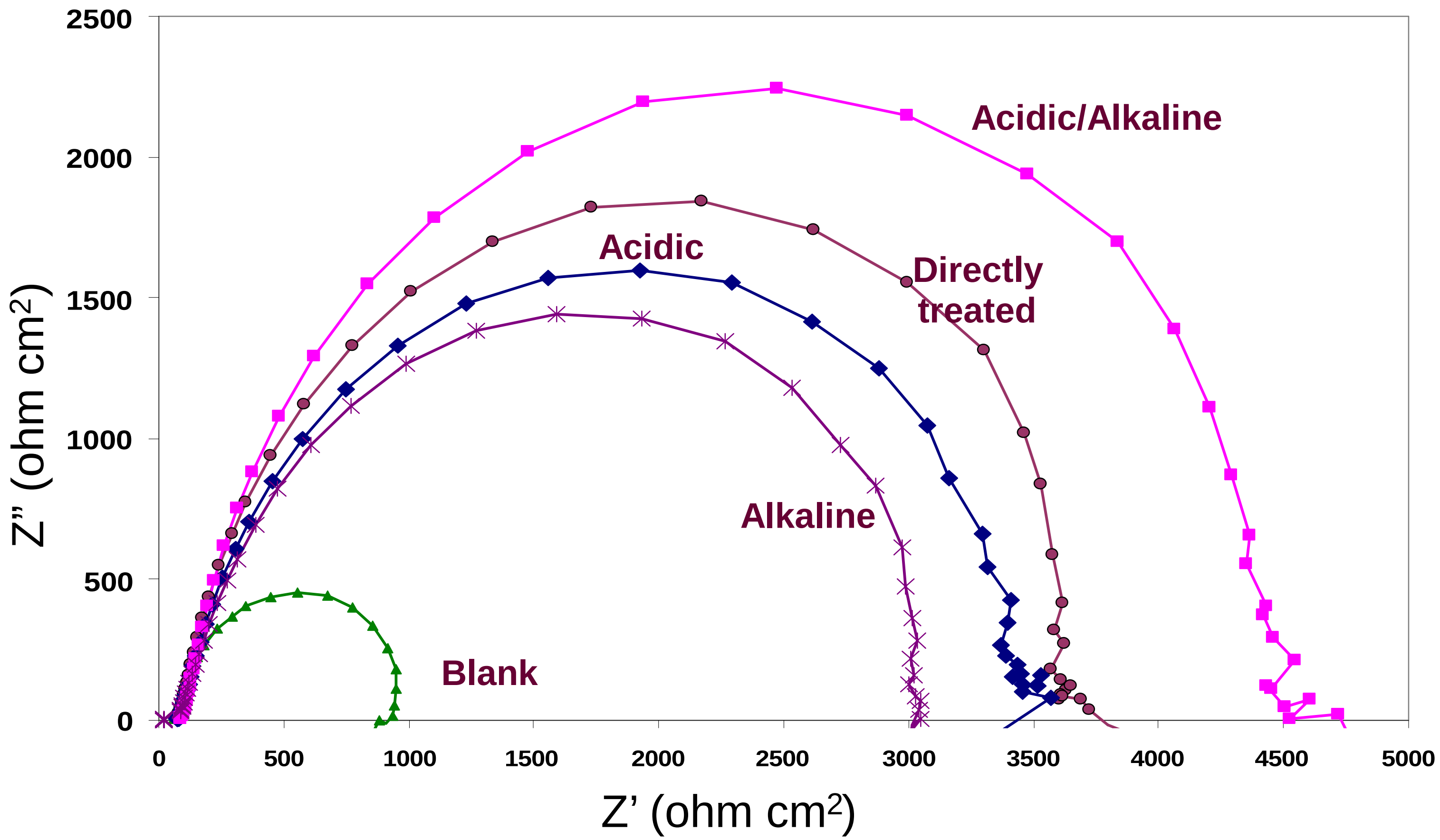
Alkaline/Acidic



Directly Treated

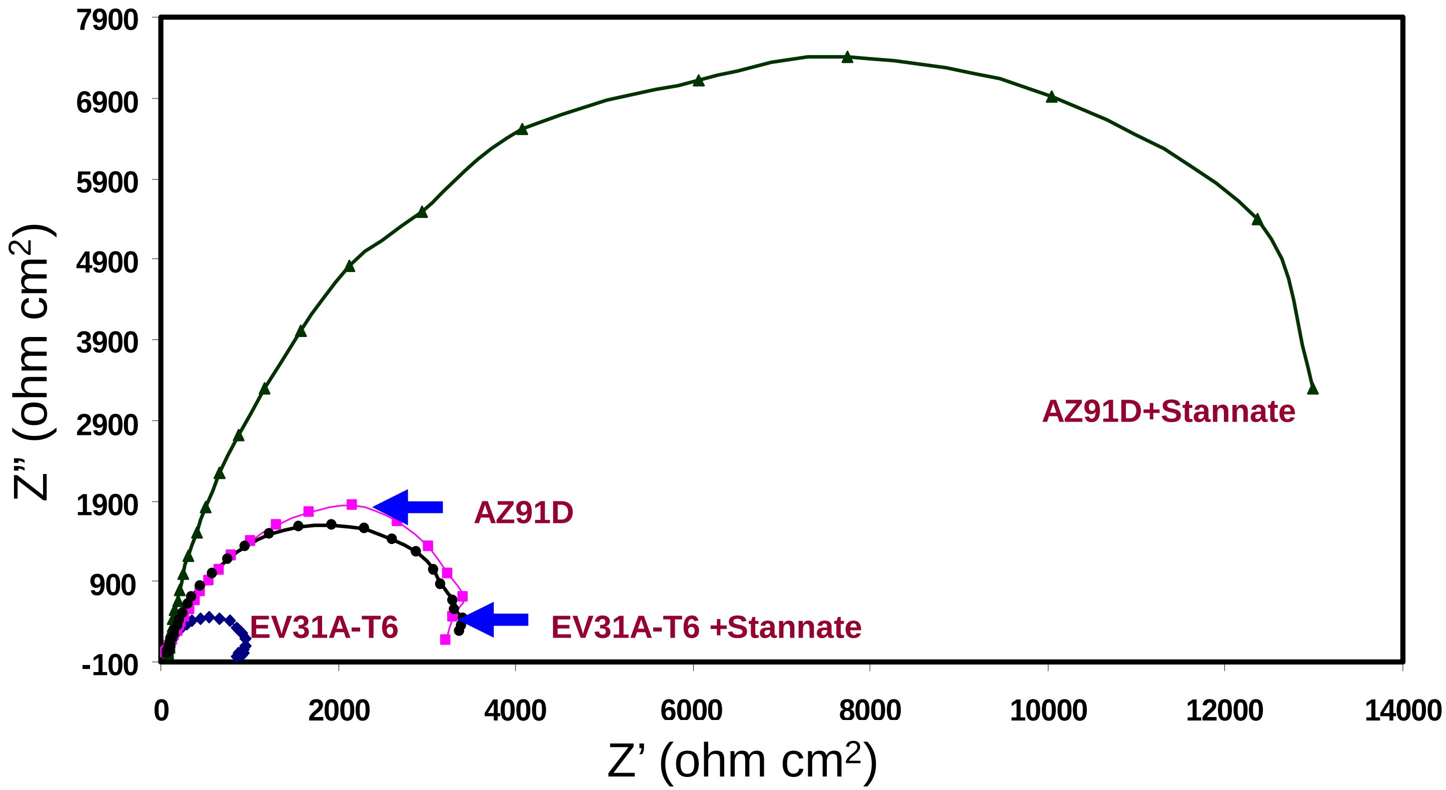


EIS Analysis of Passive Film on EV31A-T6



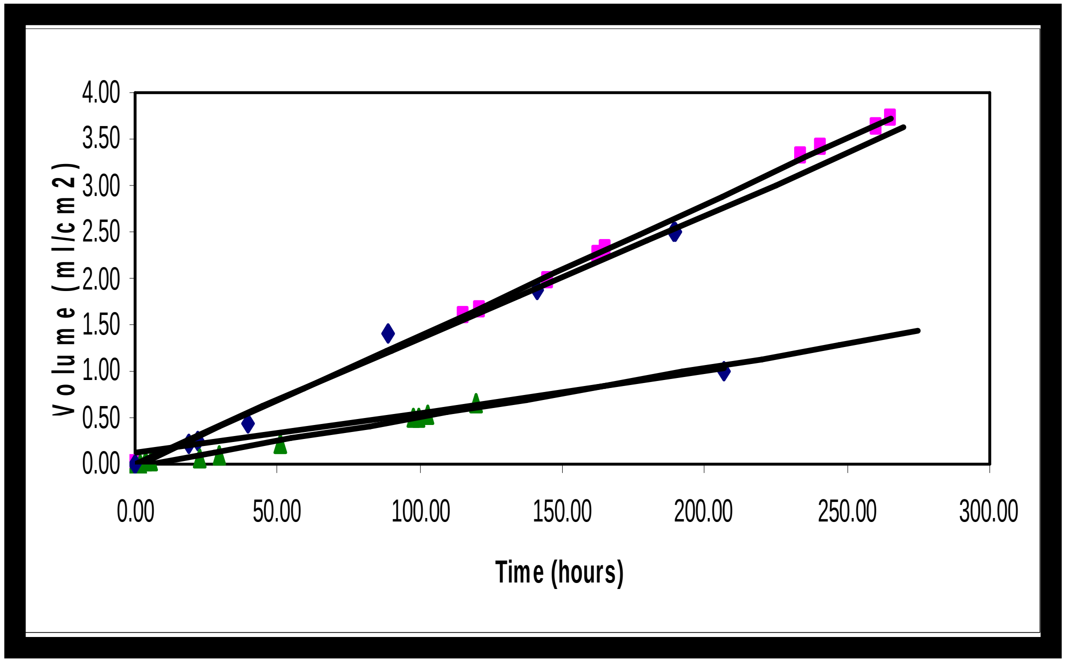
Nyquist Plots of Stannate coated EV31A-T6 after seven days in NaCl

Corrosion protection of EV31A-T6



EIS after seven days of immersion in NaCl solution (The data for the stannate coatings are for the directly treated surface pretreatment)

Hydrogen Reduction Rate on coated and Uncoated Mg Alloys



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Results for Stannate Conversion Coatings

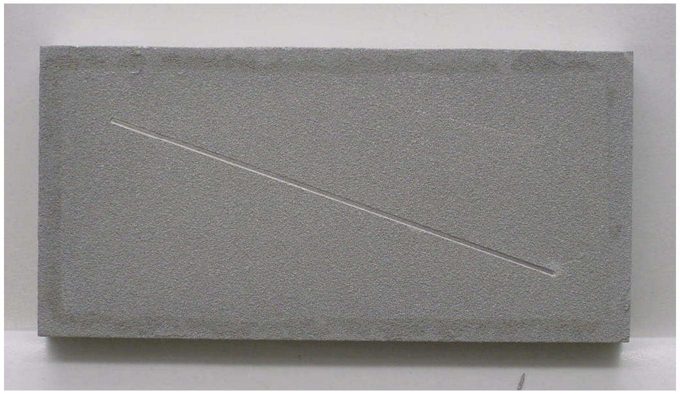
- Preliminary results indicate stannate conversion coatings decrease corrosion rates by 1/3 -1/2 and display some self-healing characteristics.
- Results indicate that surface pretreatments offer no substantial advantage over directly coating, which is advantageous from a coatings manufacturing or processing perspective.
- This is a an electroless process that could offer advantages over popular coating methods that use a surface pretreatment anodization step followed by a resin type topcoat.
- Other chemistries to include could be molybdates, tungstates, and vanadates.

Surface Engineering for Corrosion Reduction via a Sacrificial Anode Technique

ASTM B117 Test Results

2195-BT[1] 336 hours Exposure - Bare Metal

2195-BT 1000 hours Exposure
Surface Engineered Material



2519-T87 336 hours Exposure - Bare Metal

[1]BT is the "balanced temper" developed by *CTC* for optimum combinations of resistance to AP and FSP threats.

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